Modeling voice production with time-delay systems: the larynx tube

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Introduction

Time-delay systems (shortly, TDS) are also called systems with aftereffect or dead-time, hereditary systems, equations with deviating argument or differential-difference equations [1]. In voice production, TDS play a role in voice-production modeling when source and tract are coupled allowing for delayed feedback on the vocal fold dynamics [2,3]. This work undertakes the incorporation of the larynx tube to this modeling scheme, following an approach inspired in the assimilation of the larynx tube to a Helmholtz resonator, introduced four decades ago to study the singing formant [4].

Methods

The glottal source is modeled using a TDS approach that takes up the approach developed in Ref. [3]. The vocal tract is modeled in two components: the larynx tube is described using lumped elements accounting for the acoustic compliance and mass, while a classic lossy delay line accounts for the remaining downstream airways. This enables the separate control of the dynamic characteristics of the acoustic resonator. Extending the acoustical study in Ref. [4], this resonator is coupled with the mucosal wave model of the vocal folds vibration and time domain simulations are performed.

Results

The TDS including the larynx tube differs from previous approaches in the appearance of combined delay terms and derivative terms in the acoustical equation. This system is used as a voice simulator for different control parameter values, in particular the characteristics of the acoustic resonator. Numerical examples illustrate the richness of the solutions introduced by the new delay terms in the equations.

Conclusions

Modeling voice production with time delay systems can be improved if the larynx tube is included in the scheme. Time delay effects are enhanced through the incorporation of a resonator connecting the vocal source with the vocal tract. The

model has the feature of directly mapping the variation of the volume of the Morgagni sinus in a low-order model, allowing to test the articulatory interpretation of the signing formant within a theoretical framework accounting for the glottal source.

References

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